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TESTS OF A ONE-THIRD-SCALE NASA HYPERSONIC RESEARCH ENGINE INLET AT MACH NUMBERS 6 AND 8 (U)

Frederick K. Hube

ARO, Inc.

March 1968

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TESTS OF A ONE-THIRD-SCALE NASA HYPERSONIC RESEARCH ENGINE INLET AT MACH NUMBERS 6 AND 8 (U)

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FOREWORD

(U) The work reported herein was done at the request of the Air Force Aero-Propulsion Laboratory (AFAPL), Air Force Systems Command (AFSC), for the National Aeronautics and Space Administration (NASA) and the Lockheed California Company under Program Element 62405214, Project 3012.

(U) The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted during the period from July 7 to 19, 1967, under Project No. VT0770, and the manuscript was submitted for publication on December 29, 1967.

(U) This report contains no classified information extracted from other classified documents.

(U) This technical report has been reviewed and is approved.

Donald H. Meyer
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UNCLASSIFIED ABSTRACT

(U) An axisymmetric, variable geometry, hypersonic inlet was tested at Mach numbers 6 and 8 as a preliminary step in the development of the NASA Hypersonic Research Engine (HRE). Surface pressure measurements on the inlet centerbody and inside the cowl and pitot pressure measurements at two stations along the internal passage were made. The measurements were obtained at various centerbody positions, free-stream Reynolds numbers from 0.97 to 2.50×10^6, based on the 6-in. cowl diameter, and over an angle-of-attack range from -6 to +6 deg. Selected results are presented to illustrate the effects of centerbody position, angle of attack, Mach number, and Reynolds number on the surface and pitot pressure distributions.

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NOMENCLATURE

M	Mach number
p	Pressure, psia
Re_{∞_d}	Free-stream Reynolds number, based on cowl lip diameter (6.00-in.)
T	Temperature, °R
x_L	Axial distance measured from virtual apex of centerbody to cowl lip, in.
α	Angle of attack, deg

SUBSCRIPTS

o	Tunnel stilling chamber conditions
t	Pitot probe measurements
∞	Tunnel free-stream conditions

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SECTION I
INTRODUCTION

(U) A one-third-scale model of an axisymmetric, variable geometry hypersonic inlet designed as the air induction section of the NASA Hypersonic Research Engine (HRE) was tested at Mach numbers 6 and 8. The present tests were preliminary to future wind tunnel tests of a two-thirds-scale inlet model, which will simulate the complete range of anticipated full-scale flight conditions. Wall static pressures along the centerbody and inner cowl surface and pitot pressure distributions across the internal passage at two axial stations were measured to determine the performance of the inlet.

(U) The tests were conducted in the von Kármán Gas Dynamic Facility (VKF) 50-in. wind tunnel (Gas Dynamic Wind Tunnel, Hypersonic (B)) at Mach numbers 6 and 8 and free-stream Reynolds numbers from 0.97 to 2.50 x 10^6 (based on the cowl lip diameter of 6 in.). The inlet was tested with various centerbody positions over an angle-of-attack range from -6 to +6 deg.

SECTION II
APPARATUS

2.1 MODEL

(U) The model, supplied by the Lockheed California Company and shown in Figs. 1 and 2a (Appendix), was constructed of 17-4 PH stainless steel. The contour of the centerbody began with a 10-deg conical forebody, faired smoothly into an isentropic compression surface, and made an expansion turn inside the cowl into the internal passage. The cowl had a drooping lip which would allow the inlet to be closed to the external flow during power-off flight. Internally mounted electric motors were provided for remote positioning of the centerbody and mass flow plug.

(U) The inlet contained a row of static pressure orifices along the top centerline of the centerbody and on the inner surface of the cowl top centerline. Pitot pressure rakes, each with three probes, were fixed to the centerbody on the top and bottom centerlines at an axial station 14.34 in. aft of the centerbody tip. Two additional throat rakes, composed of five pitot pressure probes each, were attached to the cowl top and bottom centerlines 6.60 in. aft of the cowl leading edge.

(U) Four pitot pressure rakes in the diffuser section were positioned 15.31 in. aft of the cowl lip. Data from these rakes and adjacent static pressure orifices were used to compute the mass flow through the inlet.

(U) Preliminary tests were made to determine the optimum boundary-layer trip size to ensure a turbulent centerbody boundary layer at the cowl entrance. The trip shown in Fig. 2b was selected and used for all subsequent tests. The full-scale inlet will also use a boundary-layer trip, but this trip configuration will be determined during future tests with the two-thirds-scale model.

2.2 WIND TUNNEL

(U) Tunnel B is a continuous, closed-circuit, variable density wind tunnel with an axisymmetric contoured nozzle and a 50-in.-diam test section. The tunnel operates at a nominal Mach number of 6 or 8 at stagnation pressures from 20 to 300 and from 50 to 900 psia, respectively, at stagnation temperatures up to 1350°R. The model may be injected into the tunnel for a test run and then retracted for model cooling or model changes without interrupting the tunnel flow. A more complete description of the tunnel may be found in the Test Facilities Handbook[1].

2.3 INSTRUMENTATION

(U) Model pressures on the centerbody ahead of the cowl lip were measured with 15-psid transducers, and the internal static and pitot pressures were measured with 100- and 200-psid transducers, respectively. All transducers were referenced to a near vacuum. From repeat calibrations, the estimated precision of the pressures measured with the 15-psid transducers was ±0.003 psia or ±0.5 percent, whichever was greater. The estimated precision of the measurements made with the 100- and 200-psid transducers was ±0.10 percent of full-scale reading.

(U) Model flow field schlieren photographs were obtained during all tests. Typical photographs are in Fig. 3.

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[1] Test Facilities Handbook (Sixth Edition). "von Kármán Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, November 1966.

SECTION III
PROCEDURE

(U) The model was injected into the tunnel flow with the centerbody moved aft to ensure that the inlet was started for each test run. Moving the centerbody aft opened the throat, thereby promoting the establishment of supersonic flow through the inlet. After a start was confirmed, the centerbody was translated to the desired test position. For all data presented, the mass flow plug was moved to the most aft position, thereby providing essentially no restriction to the inlet flow. Table I contains a complete list of test conditions.

TABLE I
TEST SUMMARY

M_∞	x_L, in.	p_o, psia	T_o, °R	p_∞, psia	$Re_{\infty_d} \times 10^{-6}$
6.02	12.55	110	850	0.068	1.05
↓	12.60	↓	↓	↓	↓
	12.90				
6.03	11.85	165	1110	0.102	0.97
↓	12.00	↓	↓	↓	↓
	12.55				
	12.60				
	12.90				
6.06	11.85	285	850	0.162	2.50
↓	12.00	↓	↓	↓	↓
	12.55				
	12.60				
	12.90				
7.97	12.90	450	1295	0.047	1.05
↓	13.08	↓	↓	↓	↓
	13.31				
8.01	12.90	800	1335	0.082	1.75
↓	13.08	↓	↓	↓	↓
	13.31				

Note: The angle-of-attack range for each combination of centerbody position, Reynolds number, and Mach number was -6 to +6 deg.

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(U) The inlet performance will be evaluated by the Lockheed California Company.

SECTION IV
RESULTS AND DISCUSSION

(~~C~~) The effects of centerbody position on the centerbody and cowl pressure distributions and the forward pitot rake pressures at Mach number 8.01 are shown in Fig. 4. The peak pressures on the centerbody (Fig. 4a) and cowl surfaces (Fig. 4b) decreased in an orderly manner as the centerbody was moved aft, i.e., as the duct geometric contraction decreased. However, surface pressure variations in the neighborhood of the cowl lip were not orderly, probably because of the interaction of the lip shock and the centerbody boundary layer. Figure 4c illustrates that both pitot pressure level and distribution varied, indicating the influence of varying duct contraction and cowl lip shock interaction.

(~~C~~) Figure 5 shows the effects of Reynolds number on the centerbody, cowl, and forward pitot rake pressure distributions. Significant Reynolds number influence on surface pressures appeared to be limited to the entrance portion of the duct. Pitot pressure measurements in this region also showed a significant variation with Reynolds number (Fig. 5c).

(~~C~~) Variation of centerbody, cowl, and forward pitot rake pressure distributions with angle of attack at Mach number 8.01 is shown in Fig. 6. The pressure level on the centerbody and cowl changed uniformly with angle of attack. The pitot rake pressure distribution (Fig. 6c) showed the largest change at positive angle of attack.

(~~C~~) Figure 7 presents the effects of Mach number on the centerbody, cowl, and forward pitot rake pressure distributions at a Reynolds number of 1.05×10^6. Generally, higher static pressure ratios and lower pitot pressure ratios were observed as free-stream Mach number increased; however, the basic pressure distribution trends were unchanged.

APPENDIX
ILLUSTRATIONS

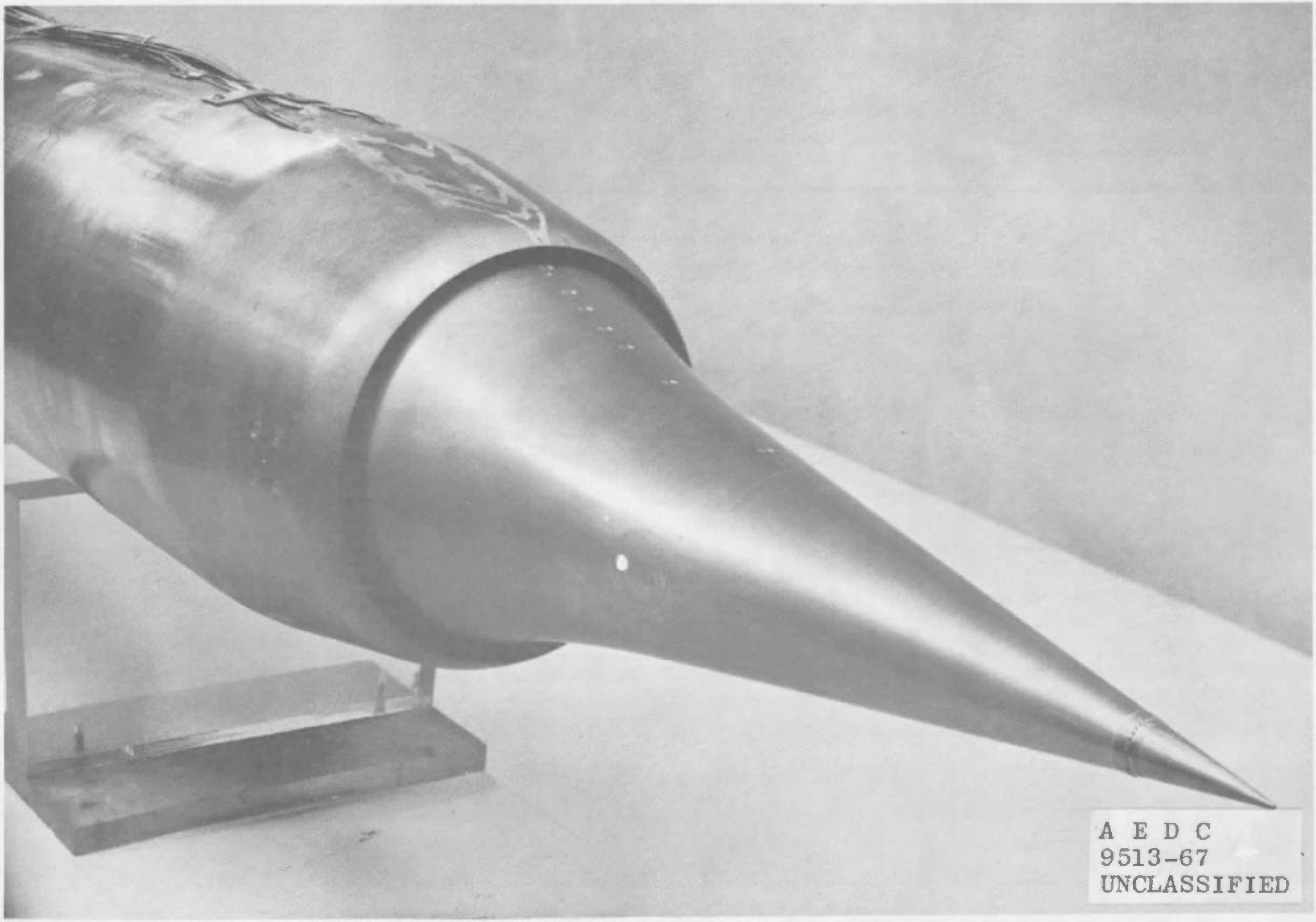
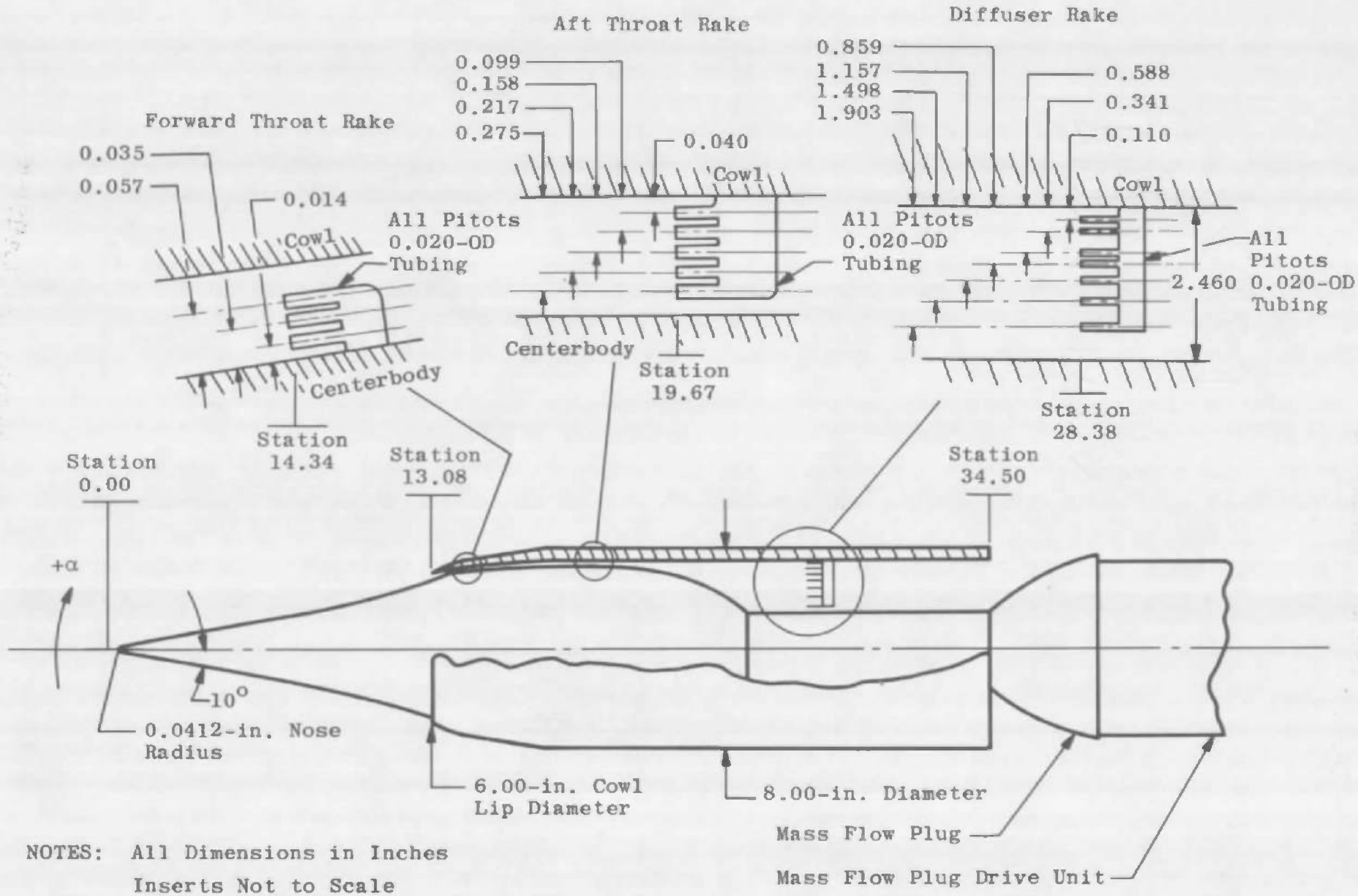
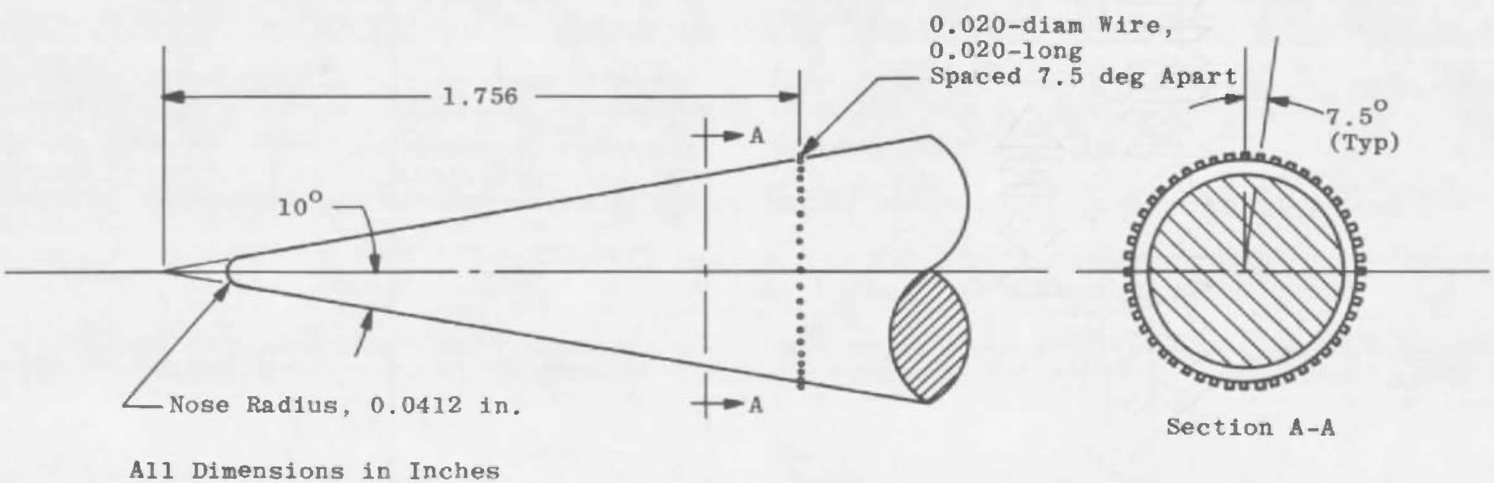


Fig. 1 Photograph of Inlet Model



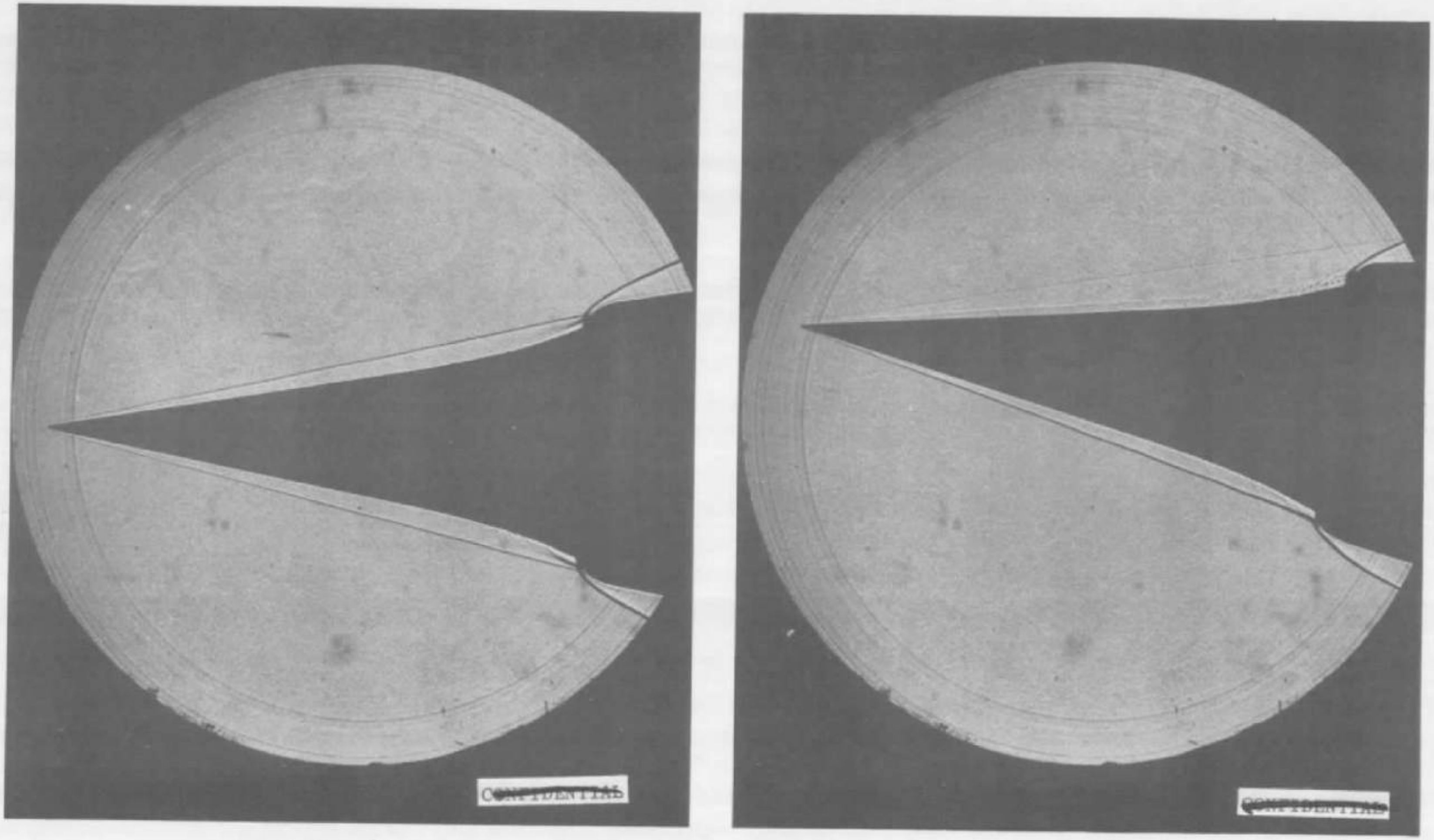
a. Inlet Model

Fig. 2 Sketch of Inlet Model and Boundary-Layer Trip



b. Boundary-Layer Trip

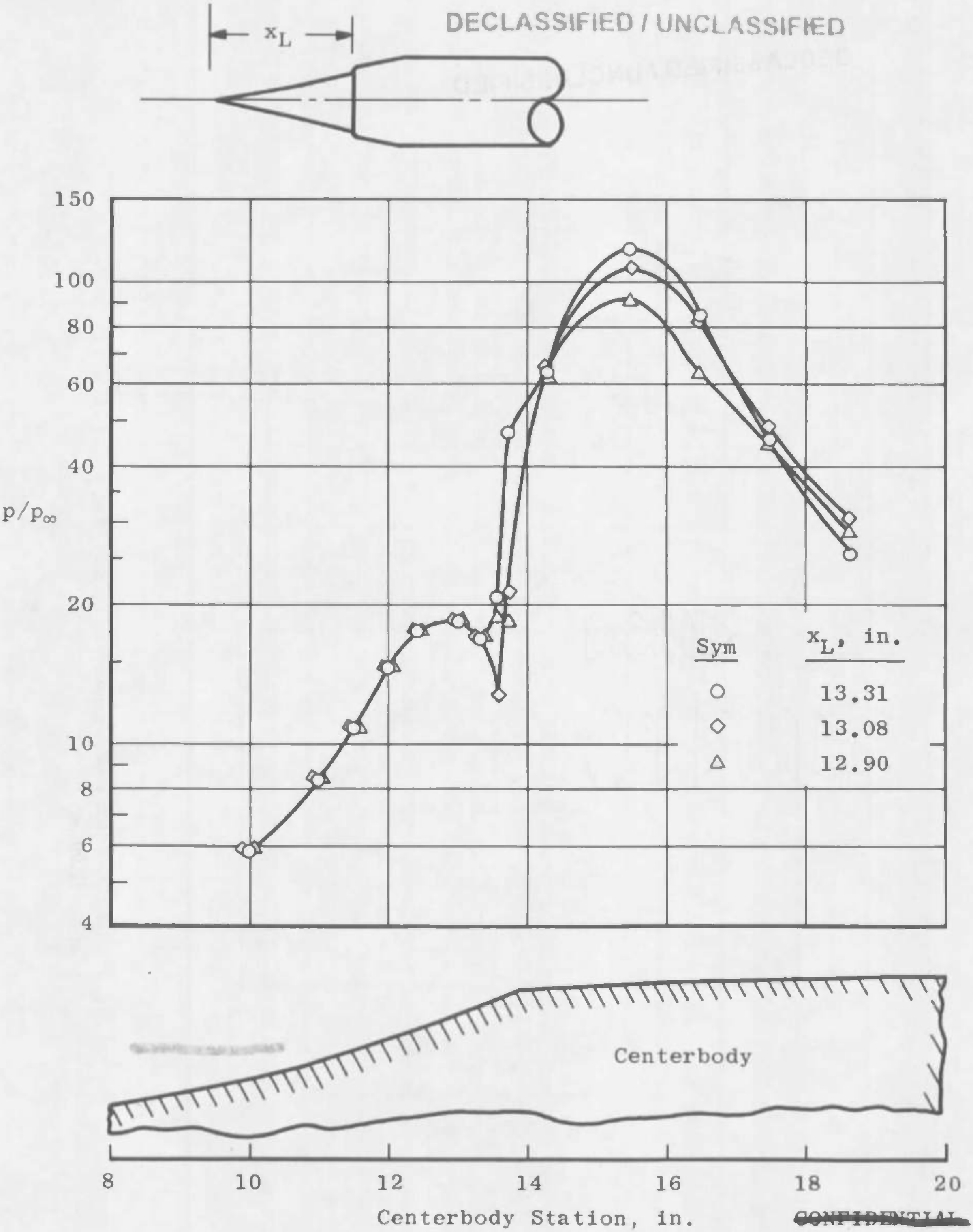
Fig. 2 Concluded



a. $\alpha = 0$

b. $\alpha = +6$ deg

Fig. 3 Inlet Flow Field Shadowgraphs, $M_\infty = 8.01$, $Re_{\infty_d} = 1.75 \times 10^6$, $x_L = 12.90$ in.



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a. Centerbody Pressure Distribution

Fig. 4 Effects of Centerbody Position on Centerbody, Cowl, and Forward Pitot Rake Pressure Distributions, $M_\infty = 8.01$, $Re_{\infty_d} = 1.75 \times 10^6$, $\alpha = 0$

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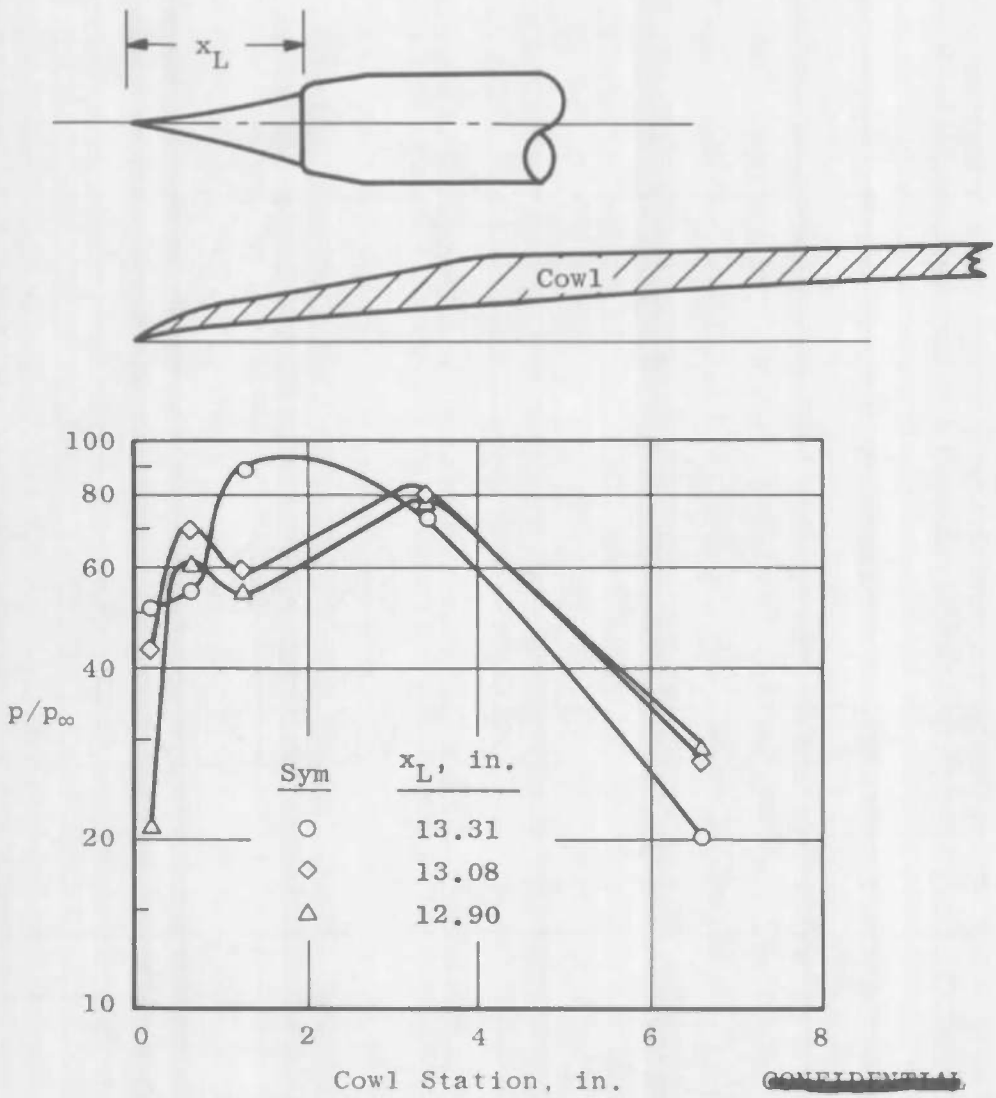

b. Cowl Pressure Distribution

Fig. 4 Continued

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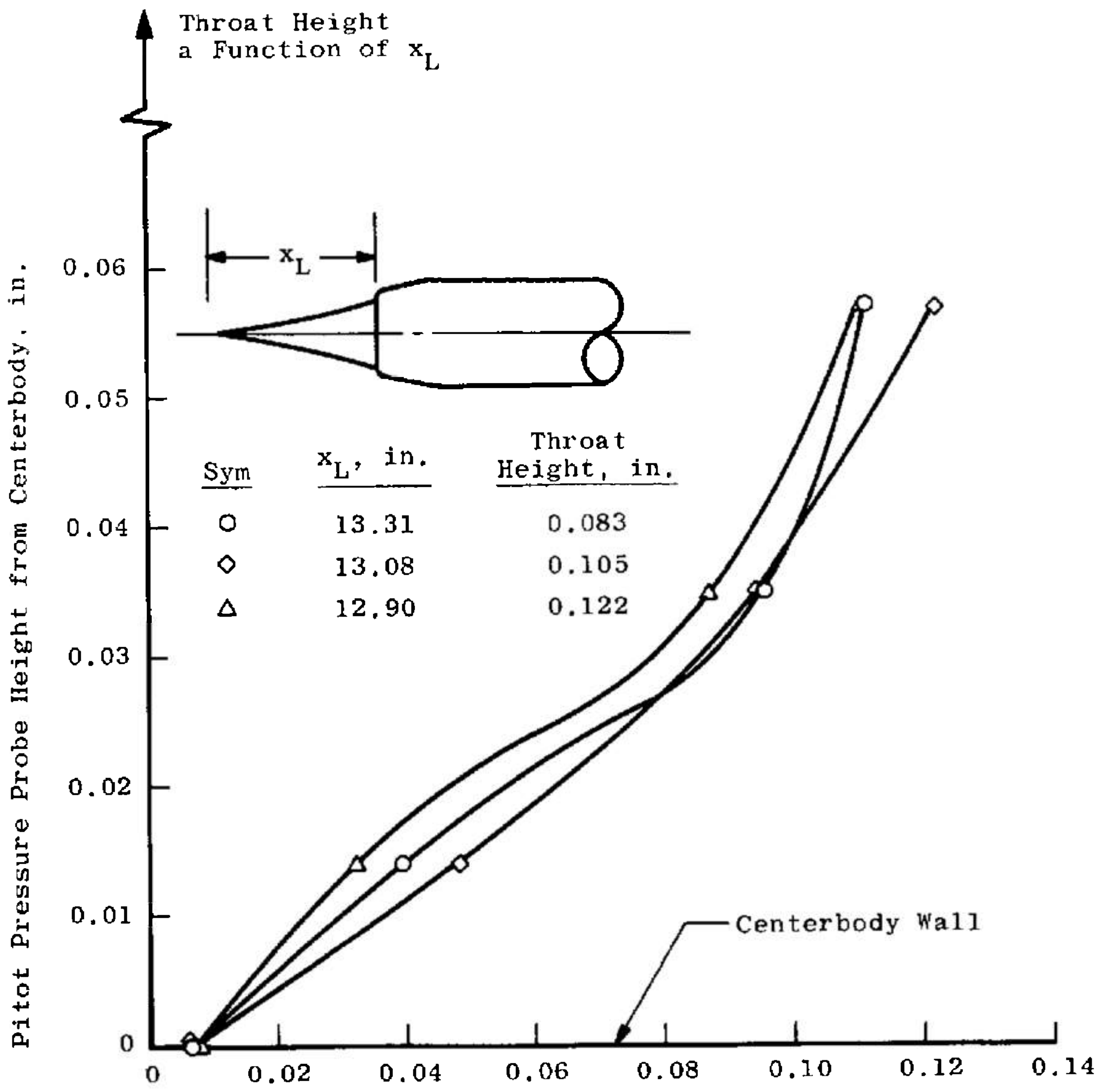

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c. Forward Pitot Rake Pressure Distribution

Fig. 4 Concluded

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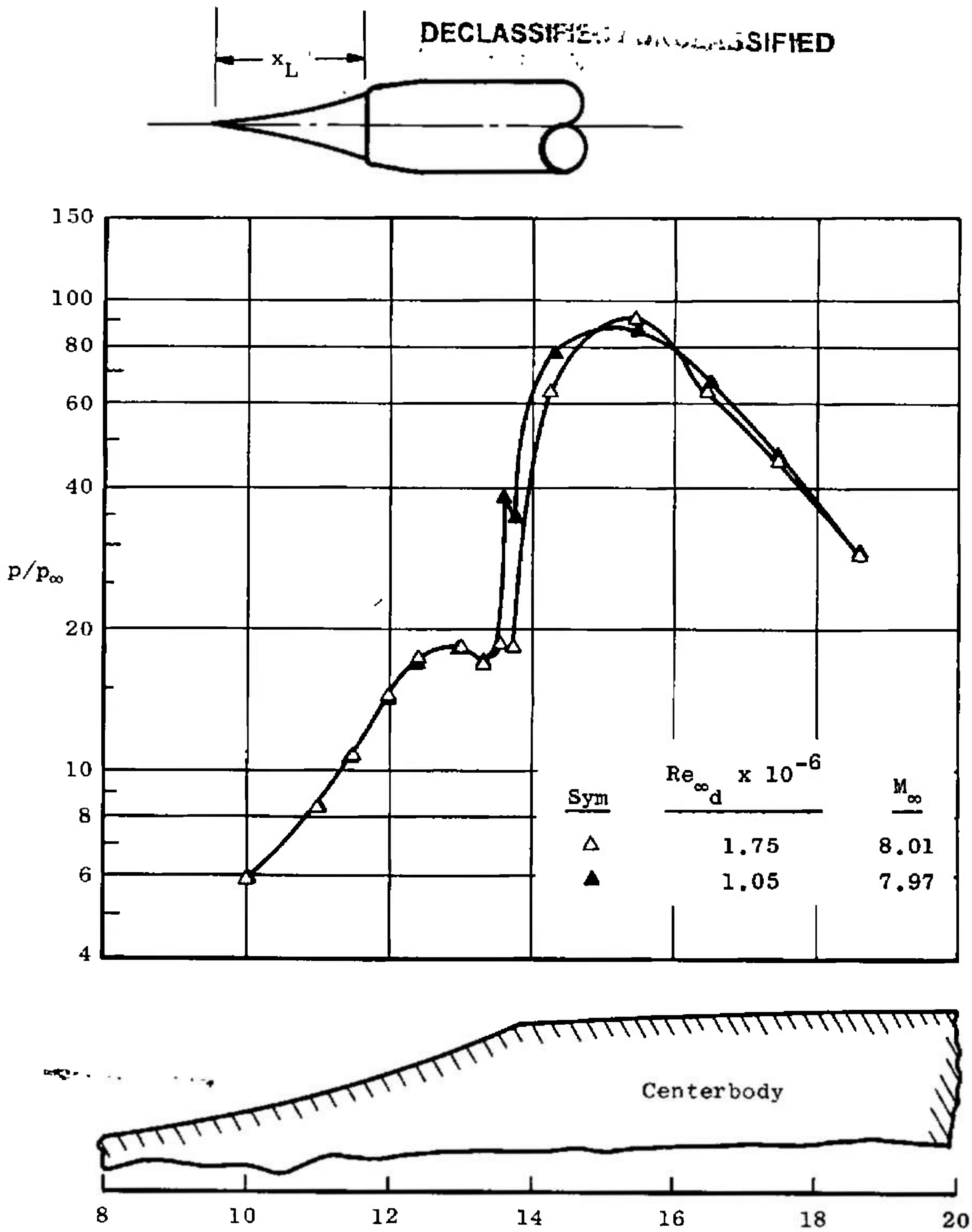

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a. Centerbody Pressure Distribution

Fig. 5 Effects of Reynolds Number on Centerbody, Cowl, and Forward Pitot Rake Pressure Distributions, α = 0, x_L = 12.90 in.

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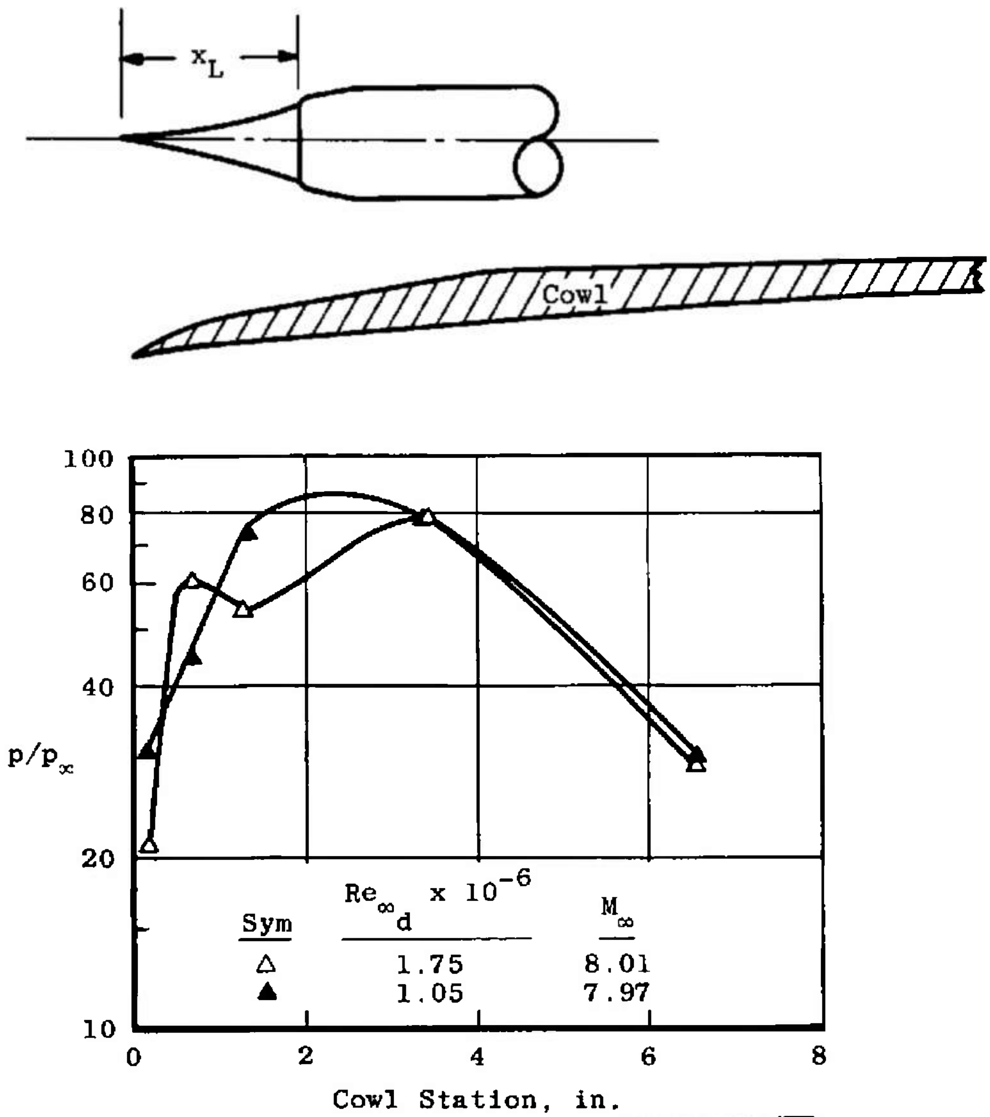

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b. Cowl Pressure Distribution

Fig. 5 Continued

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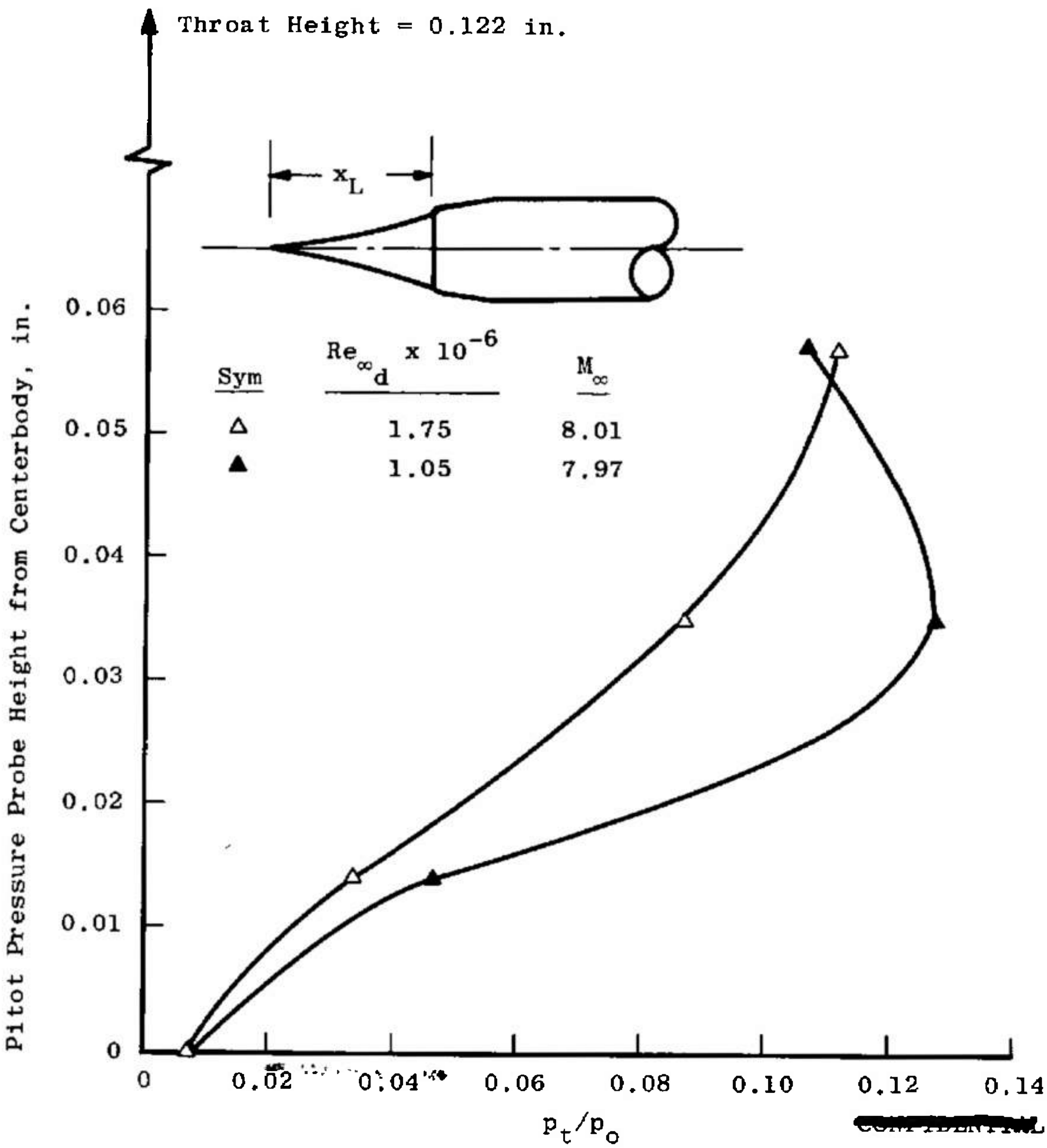

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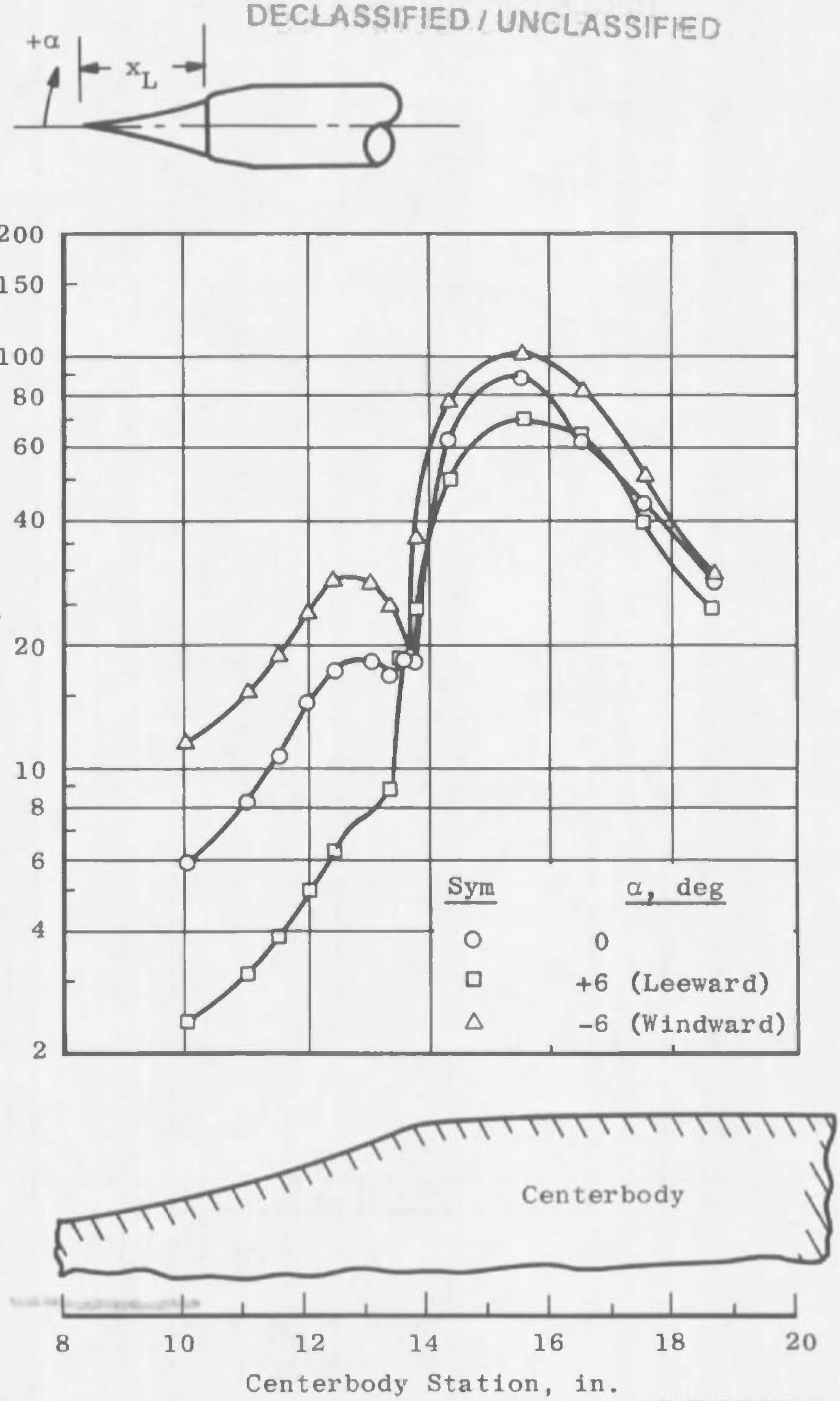
c. Forward Pitot Rake Pressure Distribution

Fig. 5 Concluded

[redacted]



a. Centerbody Pressure Distribution

Fig. 6 Effects of Angle of Attack on Centerbody, Cowl, and Forward Pitot Rake Pressure Distributions, M_∞ = 8.01, Re_{∞_d} = 1.75 x 10^6, x_L = 12.90 in.

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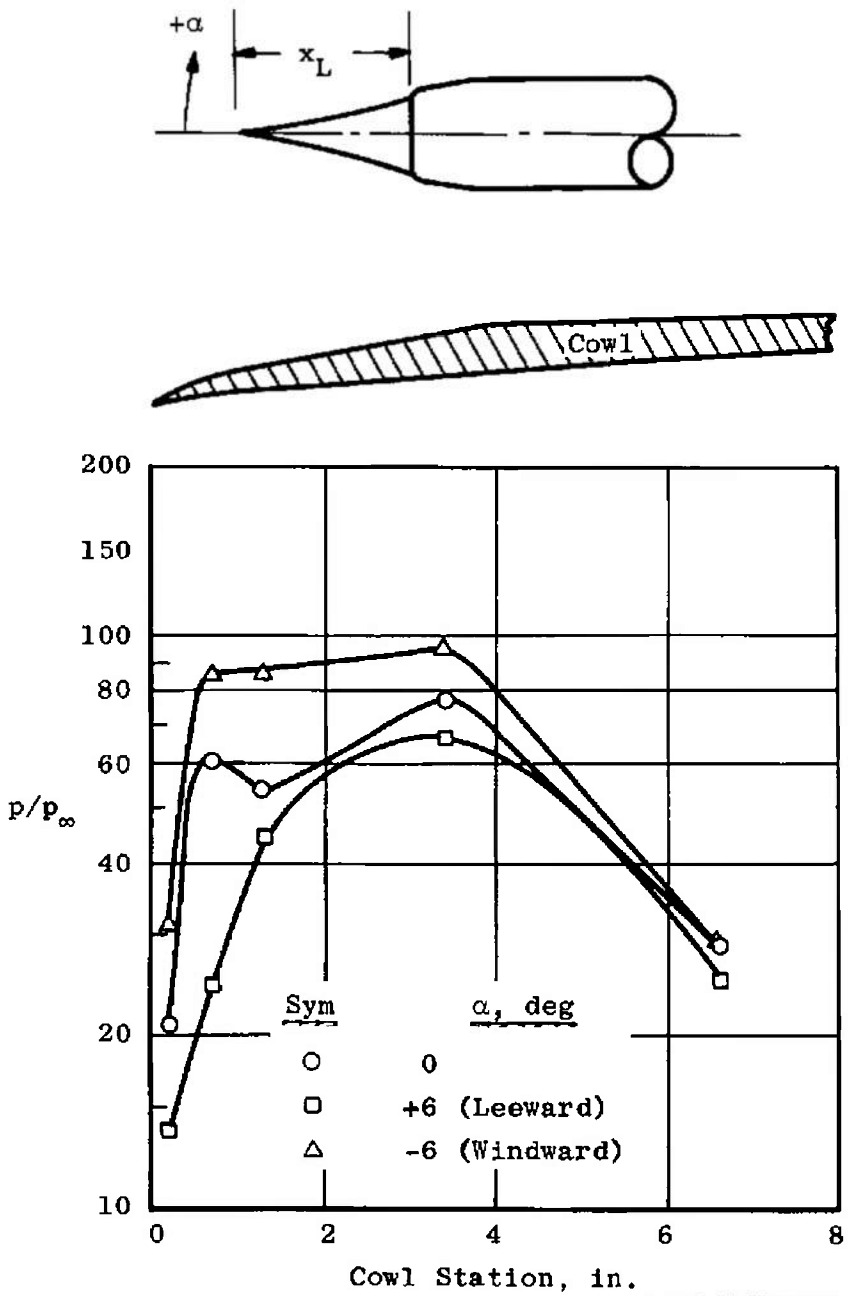

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b. Cowl Pressure Distribution

Fig. 6 Continued

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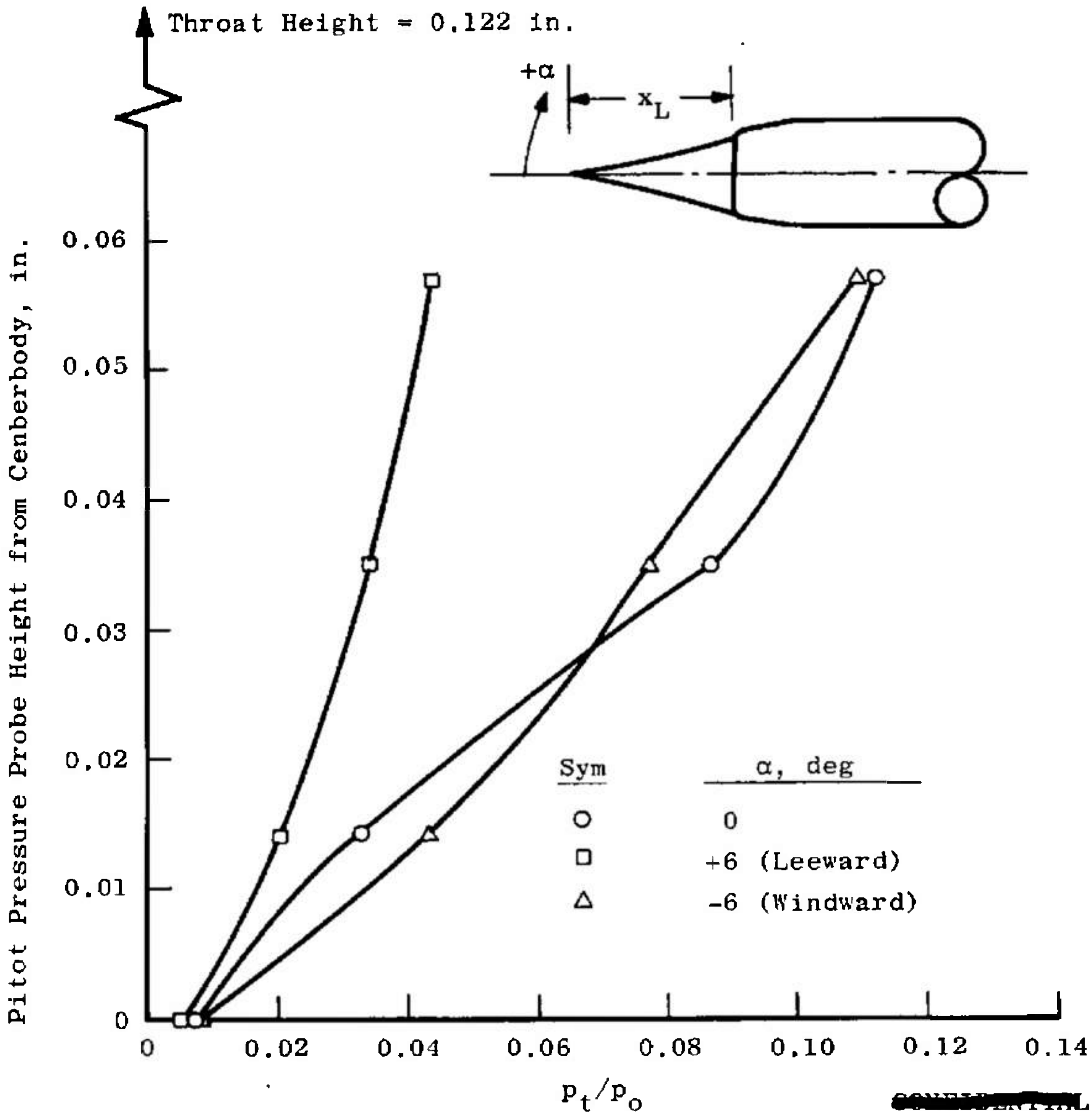
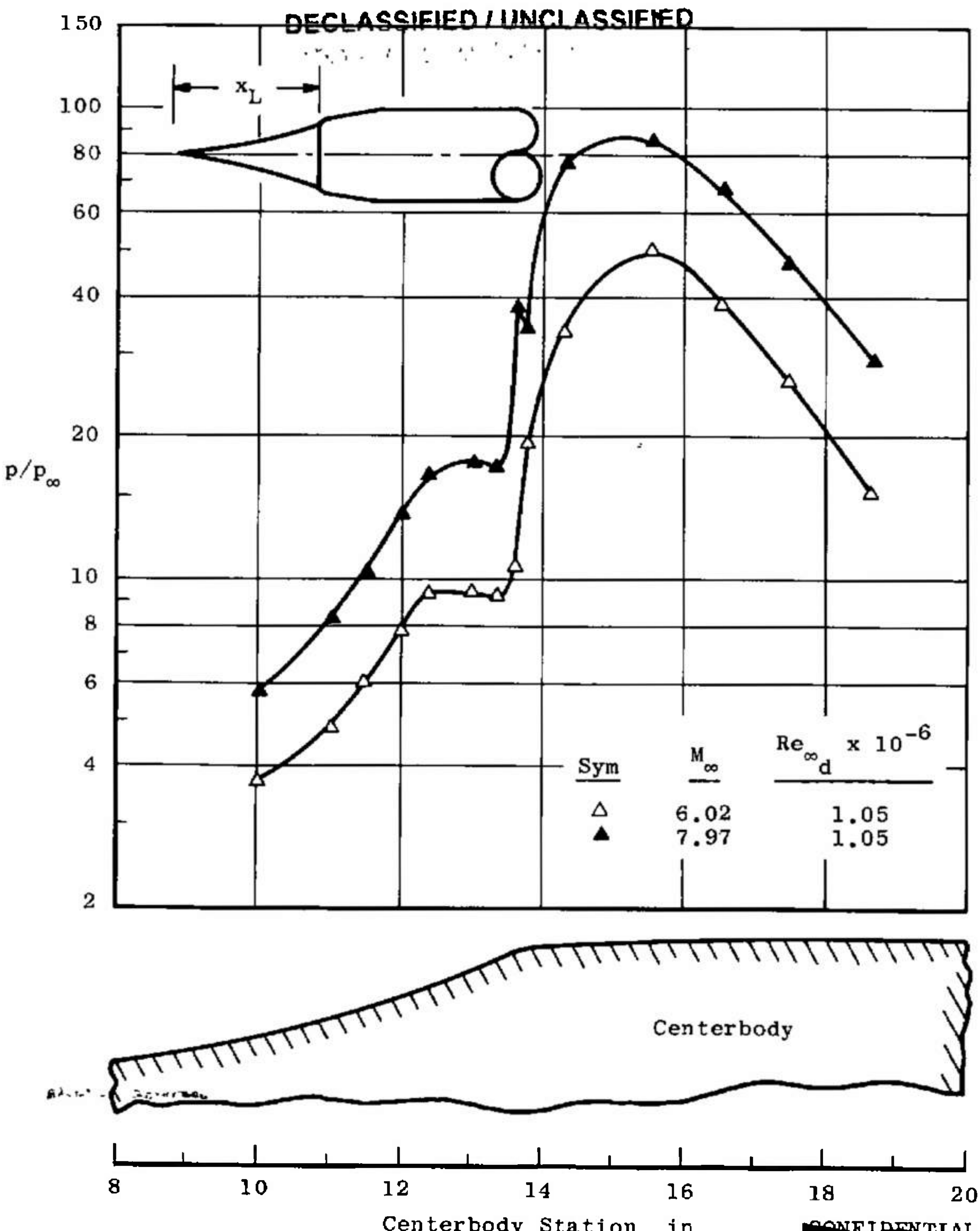


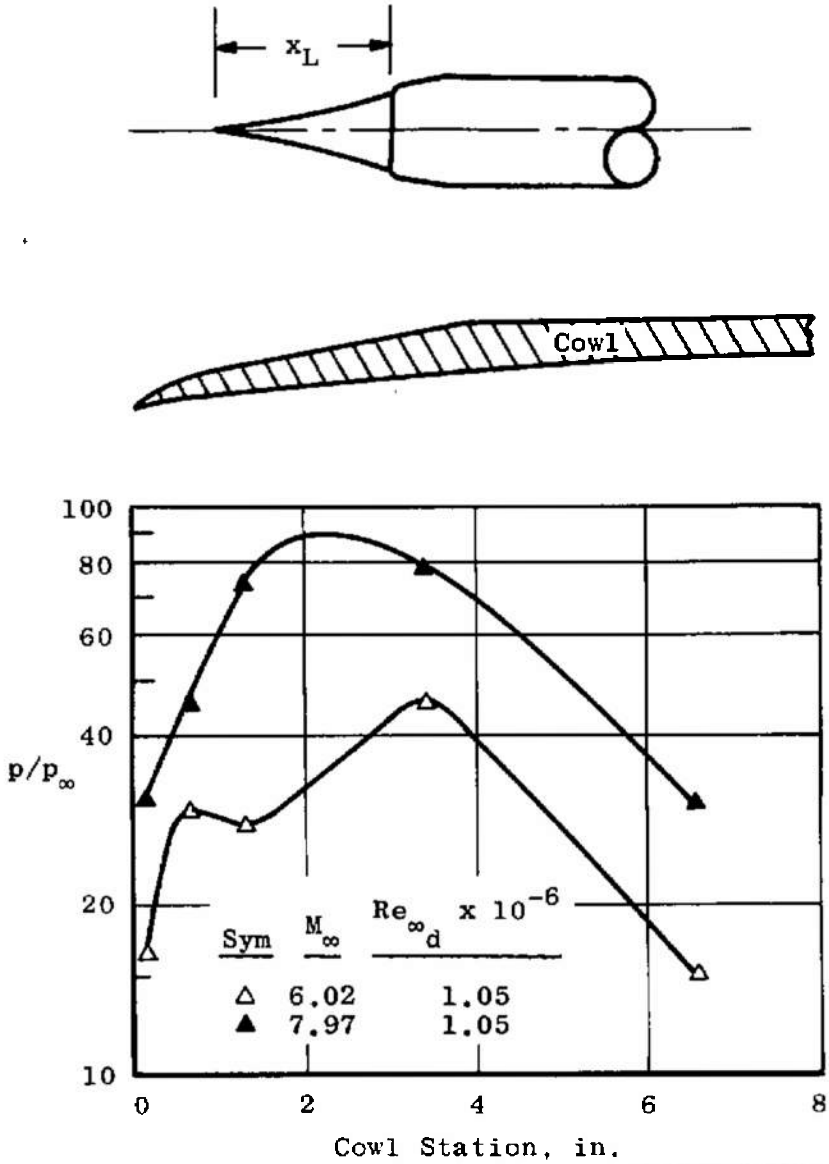
c. Forward Pitot Rake Pressure Distribution

Fig. 6 Concluded



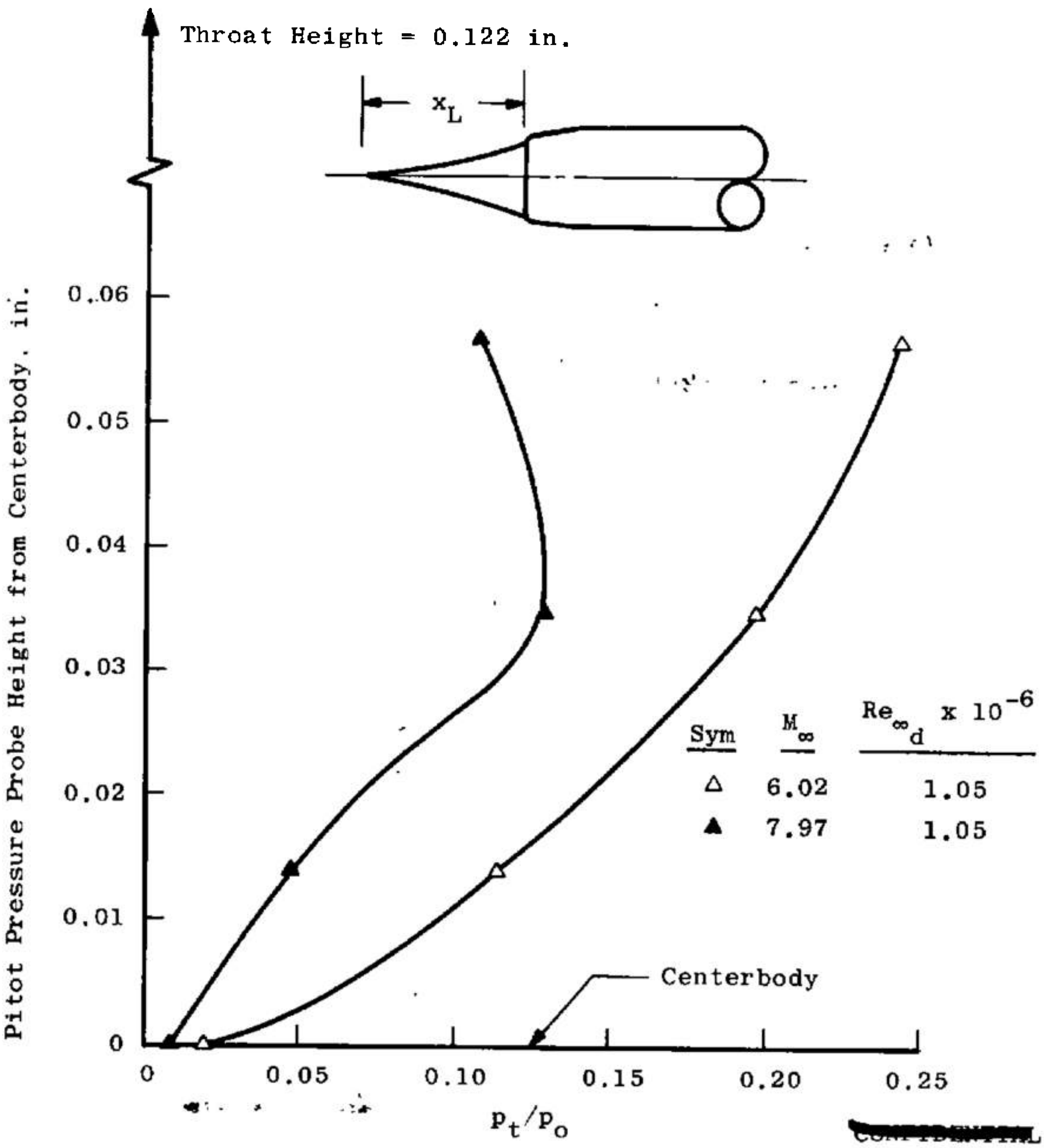
a. Centerbody Pressure Distribution

Fig. 7 Effects of Mach Number on Centerbody, Cowl, and Forward Pitot Rake Pressure Distributions, Re_{∞_d} = 1.05 x 10^6, x_L = 12.90 in., α = 0



b. Cowl Pressure Distribution

Fig. 7 Continued



c. Forward Pitot Rake Pressure Distribution
Fig. 7 Concluded

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13 ABSTRACT

An axisymmetric, variable geometry, hypersonic inlet was tested at Mach numbers 6 and 8 as a preliminary step in the development of the NASA Hypersonic Research Engine (HRE). Surface pressure measurements on the inlet centerbody and inside the cowl and pitot pressure measurements at two stations along the internal passage were made. The measurements were obtained at various centerbody positions, free-stream Reynolds numbers from 0.97 to 2.50 x 10^6, based on the 6-in. cowl diameter, and over an angle-of-attack range from -6 to +6 deg. Selected results are presented to illustrate the effects of centerbody position, angle of attack, Mach number, and Reynolds number on the surface and pitot pressure distributions. (U)

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surface pressure						
pitot pressure						
1 Scramjets						
2. Hypersonic research engine (NASA)						
4 Air inlets -- Performance						

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